

1

IONIZING RADIATION

2

BIOLOGICAL EFFECTS

3

**RADIATION PROTECTION
STANDARDS AND GUIDES**

4

CONTROL OF RADIATION EXPOSURE

5

INSTRUMENTATION

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BIOASSAY

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PERSONNEL DECONTAMINATION

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USE OF PROTECTIVE CLOTHING

9

INDUSTRIAL SAFETY

10

**PHYSICAL PROTECTION AND
EMERGENCIES**

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

O. INTRODUCTION

TP-O.1
(NRC Logo)

A. Instructor Self-Introduction

B. Administration

1. Complete course info sheets and pass in
2. Ensure Evaluation Sheets are turned in after course
3. Parking
4. Food-lunch
5. Restrooms
6. Dress casual for 2nd day
7. No Smoking in class

These are
needed to ensure
you get your
completion letter

Avoid dresses

C. Course Purpose

1. Generic SAT
2. Site Specific Training still required
3. This course supports "good guy" letter from region

Normally 5 to 30
minutes
TP-O.2
NRC resident

D. Course Schedule

1. 7:40 a.m. start time
2. 9:00 a.m. Break for Parking Meters

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**INSTRUCTOR
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3. First day ends 3:30 p.m. to meet shuttle
4. 2nd day depends on completion of exam

Make
arrangements for
transportation if
you expect to
take the full 1½
hours for exam

E. Exam

1. 50 questions multiple choice
2. 1½ hours to complete

-

F. Review Manual content and organization

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

I. IONIZING RADIATION: TYPES, QUANTITIES AND UNITS

A. Introduction

1. Section provides introduction to the types as well as the terms associated with the types ionizing radiation commonly found at nuclear plants
2. Chapter 1 Objectives

TP-1.1

B. The Atom

TP-1.2

1. Three basic sub-atomic particles
 - a. Neutron
 - Determines the isotope of a particular atom
 - Determines nuclear stability
 - Located in nucleus with protons
 - b. Proton
 - Determines the atom's atomic number
 - Located in the nucleus with neutrons

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c. Electron

- Determines the chemical stability of an atom
- To be chemically stable, an atom will have a set number of electrons

C. Ions

TP-1.3

1. Particles possessing an electrical charge, positive or negative

a. Free electrons

b. Beta particles

- The same size as an electron, but emitted from the nucleus of an atom during radioactive decay

c. Alpha particles

- Comprised of two protons, two neutrons
- Positively charged

2. Ionization

a. Occurs when an electron is removed from or added to a neutral atom

- Results in a positively charged and a negatively charged particle, or ion pair

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INSTRUCTOR NOTES/KEY AIDS

D. Radiation

1. Radiations result from unstable atoms which release energy and/or mass to become more stable or to reach a stable state

TP-1.4
Also originate
from fission
process

- a. Man-made

- X-rays
- Nuclear reactors
- Atomic weapons
- Medical radiation sources

- b. Naturally occurring

2. Radioactivity is defined as the spontaneous emission of radiation

TP-1.5

- a. Synonyms are activity and radioactivity

3. Radioactive material is defined as any material which emits radiation. It emits radiation over time due to radioactive decay.
4. Generally speaking, radiation is either ionizing or non-ionizing
5. Damage is done to cells by ionizing radiation by causing chemical ions to be generated in the cells creating an environment which is not conducive to living cells

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NOTES/KEY AIDS

6. Examples of non-ionizing radiation would be visible light from lighting fixtures, radiant heat, microwaves, etc.

E. Types of Ionizing Radiation

1. Five types of ionizing radiation TP-1.6
 - a. Alpha particle
 - b. Beta particle
 - Positively or negatively charged
 - c. Gamma Ray
 - d. X-ray
 - e. neutron particle
2. Five common types of radiation interact with neutral atoms in either a direct or indirect manner to produce ions Thus, referred to as ionizing radiation
3. These radiation types can also cause excitation of a neutral atom This occurs without ionization
 - a. Achieved by changing the energy level and stability of the neutral atom
4. Alpha Particles (α) TP-1.7
 - a. Identical to Helium nucleus
 - Two neutrons and two protons

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INSTRUCTOR NOTES/KEY AIDS

- | | | |
|----|---|--|
| b. | Large particles emanated from the nucleus during radioactive decay <ul style="list-style-type: none">• Particles have +2 charge | Size is ≈ 4 amu or 8000x mass of beta particle |
| c. | Very energetic and have highest ionization potential | Energies in MeV range |
| d. | Have lowest penetrating ability because so heavy <ul style="list-style-type: none">• Travel in short straight line patterns | TP-1.8 |
| e. | Can be shielded by a few sheets of paper or plastic, and will be stopped by the dead layer (epidermis) of the skin | |
| f. | An internal hazard to tissues | |
| g. | Source of alpha particles is primarily decay of heavy radionuclides <ul style="list-style-type: none">- • U-235, Pu-239, Nd-144 | Transuranics are alpha emitters |
| 5. | Beta Particles (β) | TP-1.9 |
| a. | Particles approximately the size of an electron | Very small mass ≈ 0.0005 amu |

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NOTES/KEY AIDS

- b. Emanated from the nucleus during radioactive decay
 - Can have either positive or negative charge depending on decay scheme
 - Beta minus (-) emission most predominant
- c. Energies in keV to MeV range
 - Lower ionization potential than α but higher than others
- d. Can travel several feet in air but have low penetrating ability
 - TP-1.8
 - Can penetrate material that an alpha cannot
 - Can be shielded by low density material such as plastic
- e. Travel in "crooked" paths as they are easily deflected by atoms
 - Due to low mass and negative charge
- f. An internal hazard to tissues and external hazard to skin and lens of eye
- g. Source of beta particles is decay of activation and fission products
 - Fe-59, I-131, Cs-137, C-14, Sr-90, Co-58 (β^+)

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**INSTRUCTOR
NOTES/KEY AIDS**

- | | | |
|----|---|---|
| 6. | Gamma (γ) and X-Rays (x) | TP-1.10 |
| a. | Electromagnetic energy | |
| | <ul style="list-style-type: none"> As the name implies (ray), they are pure energy | |
| b. | No charge, no rest mass and low ionization potential | |
| c. | Gamma rays (radiation) emanate from within the nucleus of atoms | Atoms with energies in the keV to MeV range |
| | <ul style="list-style-type: none"> Usually emitted concurrent with beta particle decay | |
| d. | X-rays are emitted from the electron shells of an atom | |
| | <ul style="list-style-type: none"> The X-ray is generated when the electrons move from outer to inner orbit or Bremsstrahlung-when high speed electrons are diverted by electromagnetic field | Can be generated by X-ray machines or natural X-ray capture |

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- e. Most penetrating of all five types and can travel several hundred feet in air
- Travels in straight paths
 - Can penetrate skin, dense tissue and effect whole body
- f. Gamma radiation is effectively shielded by:
- lead
 - steel
 - concrete (high moisture)
 - water
- g. Source of gamma rays is the decay of activation and fission products
- Fe-59, Co-60, Kr-85, Xe-133, Cs-137
6. Neutrons (n)
- a. Neutral particle with mass \approx to that of proton
 - b. Emitted from the nucleus of an atom usually during some type of fission process
 - c. Highly penetrating and can travel several hundred feet in air

TP-1.8

Due to no charge
Most occupational ionizing radiation dose is received from gamma radiation

TP-1.11

Mass \approx 1 amu

Less penetrating, than γ & x-rays

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INSTRUCTOR NOTES/KEY AIDS

- d. Have wide range of energies
 - Travel path becomes more "crooked" as they slow down
 - e. Have the lowest ionization potential of the five types
 - Ionization is indirect, normal interaction is collision with other atoms
 - f. Whole body exposure problem, both an internal and external hazard
 - g. Will decay into a proton and beta (-) particle pair after about 10 minutes
 - h. Source of neutrons is primarily nuclear fission of reactor fuel (U-235, U-238)
 - Other sources include:
 - Spontaneous fission (Cf-252, Pu-239) and bombardment of beryllium with alpha particles
7. Summary of the characteristics of ionizing radiation

Less than one
eV→MeV

Neutron source
inside the body
very unlikely

If still a free
neutron

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INSTRUCTOR NOTES/KEY AIDS

F. Quantities and Units

1. Quantity is description of physical concept
2. Unit is magnitude or measure of that quantity

3. Radioactivity (Curie)

TP-1.12

- a. Quantity describing the number of decays/unit time (dps)
 - Independent of type of radiation
- b. Unit of radioactivity is Curie (Ci)

Note-Not required to memorize these numbers

- $1 \text{ Ci} = 3.7 \times 10^{10} \text{ decays/sec (dps)}$
- $\text{mCi} = 3.7 \times 10^7 \text{ dps}$
- $\mu\text{Ci} = 3.7 \times 10^4 \text{ dps}$

37 billion dps;
mCi, μCi
more commonly used

4. Specific Activity (Ci/g)

TP-1.13

- a. "Concentration" of radioactive material
 - 1 milligram $\text{Co}^{60} \approx 1 \text{ Ci}$
 - "large pile" Uranium = 1 Ci
- b. Indicates how much material is needed to produce a certain decay rate

Activity/unit mass

Higher Sp A,
Greater hazard

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5. Half-Life ($T_{1/2}$)

TP-1.14

- a. Length of time required for $\frac{1}{2}$ of the radioactive atoms to decay

- $T_{1/2}$ is unique to each radionuclide

- b. $T_{1/2}$ characterizes the rate of decay of a radionuclide

TP-1.15

- c. Examples

- What fraction of the original quantity of a radionuclide will be left in 2 half-lives?
Answer: $\frac{1}{4}$

- What % of the original quantity of a radionuclide will decay away in 4 half-lives?

Answer: 93.75%

6. Exposure-Roentgen (R)

TP-1.16

- a. Amount of ionization (charge) produced per unit mass of air due to photon radiations

- Radiation Field which is present (photons in air)

"What you could be exposed to" not dose you will receive

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- b. Unit is Roentgen (R)
- $1 \text{ r} = 0.000254 \text{ coul/kg air}$
7. Absorbed Dose (rad)
- a. Measure of the energy deposited in living tissue
- b. Does not take into account that different radiation types are not equally effective in causing biological damage or change
8. Dose Equivalent (rem)
- a. Obtained by multiplying the absorbed dose (rads) X Quality Factor
- Rem = Roentgen equivalent man
- b. Quality Factor (Q)-Weigh each type of radiation by its ability to produce biological damage in living tissue
- Dependent on radiation's Linear-Energy-Transfer (LET)
- Radiation types which transfer higher amounts of energy over a short distance (high LET's) have higher Q's

Named after Wilhelm Roentgen who discovered x-rays
Note: Revised 10 CFR 20 does not use Roentgen

- Radiation Absorbed Dose

100 rad = 1 gray

rem = rad x Q

TP-1.17

TP-1.18

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9. Dose Rates

TP-1.19

- a. Rate at which exposure or dose is occurring

Measured in
terms of time

$$\text{dose rate} = \frac{\text{dose}}{\text{time}}$$

$$(\text{STAY TIME}) = \frac{\text{dose allowed ("limit")}}{\text{dose rate ("dose receiving")}}$$

- b. Example:

How long would a worker be allowed to stay
in an area with a dose rate of 5 rem/hr if his
allowed dose is 250 mrem?

Answer:

$$\text{time (hr.)} = \frac{.250 \text{ rem}}{5 \text{ rem}}$$

$$= 0.05 \text{ hr}$$

$$\text{time (min.)} = 0.05 \text{ hr} \times \frac{60 \text{ min}}{1 \text{ hr}}$$

$$\text{time (min.)} = 3 \text{ minutes}$$

10. Summary of Quantities and Units

Refer class to
Table 1-2B in
Appendix for
review

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**INSTRUCTOR
NOTES/KEY AIDS**

II. BIOLOGICAL EFFECTS

A. Introduction

1. Section provides overview of the biological effects resulting from exposure to ionizing radiation
2. Chapter 2 Objectives

TP-2.1

B. Acute Vs. Chronic Exposure

1. Acute exposure to radiation is receiving a high dose in a short period of time
2. Chronic Exposure is low doses of radiation over a long period of time
 - a. Typifies occupational radiation exposure

TP-2.2

TP-2.3

C. Radiation has one basic biological effect and that is on cells

1. Acute radiation doses tend to kill cells
 - a. Can kill so many cells that tissues or organs are damaged
 - b. Causes rapid "whole body" response or Acute Radiation Syndrome

Expression of the cumulative lethal effect of radiation on many cells

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2. Chronic doses tend to damage (or change) cells
 - a. Don't necessarily cause immediate problem to any tissue or organ
 - b. The "cellular changes" may develop into cancer over the years

3. Internal vs. External Exposure

TP-2.4

- a. Internal exposure - radiation exposure from radioactive sources inside the body
 - Enters body through
 - Inhalation
 - Ingestion
 - Absorption
 - Injection
- b. External exposure - radiation exposure from radioactive sources outside the body

D. Radiation Effects

TP-2.5

1. Result from interactions of radiation with the atoms of molecules of which cells are made

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**INSTRUCTOR
NOTES/KEY AIDS**

2. Direct Vs. Indirect Effects

- a. Direct effect is one in which radiation interacts with atoms which are critical to the survival of the cell
 - Example: the atoms needed to ensure the cells ability to reproduce
 - Chromosomal damage to DNA

3. Indirect Effects

- a. Most cells are made up of water and likelihood of radiation to interact with the life-sustaining atoms in a cell are small
- b. More likely for radiation to interact indirectly with water molecules and form free radicals which can recombine to form toxic compounds which can destroy cells
 - Example: hydrogen peroxide (H_2O_2)

E. Cell Sensitivity

Not all equally sensitive

- 1. Cells which replicate more quickly are more sensitive than ones more dormant
 - a. Replicating cells are dependent on correct order of DNA information in order to survive
 - Direct radiation interaction results in cell death
 - b. Dormant cells have little effects from direct interaction with radiation

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**INSTRUCTOR
NOTES/KEY AIDS**

- 2. Cell sensitivity is based on rate of replication TP-2.6
 - a. Lymphocytes and blood forming cells-most sensitive
 - b. Reproductive and gastrointestinal cells-very sensitive
 - c. Nerve and muscle cells-least sensitive
- 3. Organ sensitivity correlates with cell sensitivity TP-2.7
 - a. Blood forming organs-most sensitive
 - b. Reproductive and gastrointestinal tract-very sensitive
 - c. Skin-sensitive
 - d. Muscle and brain-least sensitive
- 4. Must also consider relative importance of cells to overall body survival
 - a. Blood, GI and reproductive systems most important to body survival
- 5. Example: Malignant tumor/radiation therapy
- 6. Example: Embryo/Fetus

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F. High Doses

TP-2.8
"plume"

1. High doses of radiation have been received from workplace accidents and other tragic events

Site examples
Rare at nuclear
power plants

- a. Radiation worker deaths from criticality accidents and irradiator accidents

2. Biological effects of radiation exposure depend on

TP-2.9

- a. Total dose
- b. Time interval over which dose is received
- c. Volume of tissue exposed
- d. Type of radiation

3. Biological effects increase as:

TP-2.10

- a. Dose increases
- b. Volume of tissue exposed increases
- c. Time interval between doses decreases

Acute more
damaging than
chronic = less
time to repair

- d. LET of radiation increases

More energy
transfer per unit
distance in vital
organs

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INSTRUCTOR NOTES/KEY AIDS

- | | |
|--|--|
| <p>4. LD 50/30</p> <p>a. Dose at which 50% exposed will die within 30 days (or 60 days) without medical treatment</p> <p>b. LD 50/30 \approx = 400 rad</p> <ul style="list-style-type: none">• At 200 rad some will die, above 600 rad nearly all die• Medical treatment can influence dose response curve, but only effective for doses <u>below</u> 1000 rad• >1000 rad fatal <p>c. LD 50/30 provides statistical estimate</p> | <p>Sometimes called LD 50/60
TP-2.11
(curve)</p> <p>In short time interval</p> <p>Does not indicate any one individual's probability</p> |
| <p>5. Biological factors influencing an individuals response to radiation exposure</p> <p>a. Age</p> <ul style="list-style-type: none">• Immature organisms (younger) more sensitive than fully developed mature organisms• Very old organisms more sensitive than middle aged ones | <p>TP-2.12</p> <p>Embryo vs. middle aged adult</p> <p>Inability to repair damage as quickly</p> |

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LESSON OUTLINE

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- b. Genetic Constitution
 - Differences in each individuals chromosomal traits (sensitivities)
- c. Sex
 - Females slightly less radiosensitive than males
- d. Health
 - Individuals in poor health are more radiosensitive
 - Radiation can cause increase in sickness level
- e. Diet
 - Proper diet results in higher resistance to radiation
- 6. Acute Radiation Syndrome (ARS)
 - a. Symptoms/signs
 - Initial include: nausea, vomiting, fatigue and loss of appetite
 - Three levels of effects (syndromes)

Due to
hormonal
differences

Impaired ability
to repair

Effects on
immune system

TP-2.13
Usually a whole
body exposure
(total body
irradiation)

Below 200 rad
these may be
only symptoms
which are
indicative of
common flu

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b. Hematopoietic (Blood System) Syndrome

TP-2.14

- Organ Exposed-Bone marrow
- Threshold-100 rad
- Duration of initial symptoms \approx 2-3 days
- Latency Period (feeling OK) \approx 2-3 weeks
- Prognosis-Over 200 rad, death possible within 2-8 weeks
- Effects - blood variations detectable by medical evaluation
- Cause of Death-infection, bleeding anemia
- Treatments-transfusions, antibiotics, isolation, bone marrow transplant

c. Gastrointestinal (GI) Syndrome

TP-2.15

- Organ Exposed-Intestinal lining villi
- Threshold- \approx 500 rad
- Duration of initial symptoms \approx 2-3 days
- Latency period \approx 3-5 days
- Prognosis-over 1,000 rad death likely within 3-14 days

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- Effects-nausea, vomiting, diarrhea
 - Cause of death-infection, bleeding, dehydration, electrolyte imbalance, circulatory collapse
 - Medical treatment-none/make patient comfortable
- d. Central Nervous System (CNS) Syndrome
- Organ Exposed-brain
 - Threshold \approx 2,000 rad
 - Not much time for initial symptoms - possible disorientation
 - Latency period- \approx 15 min.-3 hours
 - Prognosis-over 5,000 rad death likely within 3 days
 - Effects-Lethargy, convulsions, tremors, loss of muscle control, coma
 - Cause of death-respiratory/circulatory collapse
 - Medical treatment-none/make patient comfortable

In addition to
blood system
syndrome

TP-2.16
Often referred
to as Cerebro-
vascular
syndrome-brain's
inability to
control muscles

In addition to
Blood and GI
syndromes

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7. Other high dose effects

TP-2.17

a. Skin

- Result usually from a low-energy X, γ or β radiation
- Doses required are usually 300 rad and up
- Signs: reddening like sunburn, peeling, blistering, hair loss

Energy is mostly deposited in skin surface

b. Cataracts

- Threshold about 200 rad
- Neutrons effective in producing cataracts due to high quality factor and high water content of eye

Water effective in stopping neutrons

c. Sterility

- Requires significant doses to reproductive cells
- In males, (lower end of required dose range) sterility may be temporary
- 400 rad and above sterility may be permanent

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NOTES/KEY AIDS

G. Low Doses

- | | |
|---|---|
| 1. Greatest concern is formation of non-lethal mutations in cells-(cancer) | Much more likely an effect of chronic doses |
| 2. Three categories of chronic effects | TP-2.18 |
| a. Genetic | |
| • Effects suffered by future offspring of individual exposed | Exposed individual's reproductive system effected |
| b. Somatic | |
| • Effect suffered by individual exposed | "Carcinogenic effect" |
| c. In-utero | |
| • Effect suffered by developing, embryo/fetus (<u>actually</u> a special somatic effect) | Different from genetic effect |
| 3. Genetic Effect | |
| a. Mutation of reproductive (sperm, egg) cells which are passed to offspring | |

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INSTRUCTOR NOTES/KEY AIDS

- b. Sources of genetic mutations:
 - Physical-radiation
 - Chemical-many chemicals
 - Biological-viruses
- c. NOTE: Radiation increases spontaneous mutation rates. Does Not Create New Mutations
- d. Risk of mutations is directly proportional to dose with no threshold
 - Therefore, doses should be kept ALARA
- e. Genetic effects to this date have not been conclusive
 - Perhaps because the mutated egg/sperm would result in a spontaneously aborted non-viable organism
- 4. Somatic Effects
 - a. Most significant risk is from occupational exposure (also is most well documented)
 - Reg Guide 8.29

TP-2.19
"Creature"

System would
not "accept it"

Cancer
formation

TP-2.20

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NOTES/KEY AIDS

- b. Carcinogenic agents:
 - Physical-radiation
 - Chemical-cigarettes, many chemicals, etc.
 - Biological-viruses
- c. Examples of radiation induced cancer in populations TP-2.21
- d. Risk
 - Risk of cancer determined from data at high doses and estimates at low doses Reg Guide 8.29
 - NRC adopts linear, non-threshold dose response curve (most conservative) TP-2.22
Discuss linear relationship
 - Indicates that there is no dose so low that it will not have some effect
- e. Incidence/Mortality TP-2.23
 - Risk estimates for radiation induced cancers is \approx 2-10 excess cases per 10,000 exposed to 1 rem 1 in 4 chance of developing cancer regardless
 - Risk of dying from cancer is $\frac{1}{2}$ risk of getting cancer
 - More exposure = more risk of cancer

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5. In-Utero Effects

- | | |
|---|---|
| a. Radiation is also capable of producing physical malformations during fetal development | "Teratogenic" effects |
| b. Effects of in-utero exposure: | TP-2.24 |
| • Intrauterine death | |
| • Growth retardation | |
| • Development abnormalities | |
| • Childhood cancers | |
| c. Probability and magnitude of effects are unfluenced by <u>dose</u> and <u>stage of fetal development</u> | TP-2.25 |
| • Risk is highest during first trimester | Organs developing |
| • Risk of childhood cancer about same as adults, however, the risk of <u>all</u> in-utero effects is about 1-10/1,000 exposed | |
| • Normal risks of fetal abnormalities are \approx 5-30/1,000 live births | Medical procedures is largest source of in-utero exposure |

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d. Reg Guide 8.13

TP-2.26

- Recommends dose to embryo/fetus (pregnant worker) be kept less than or equal to 0.5 rem during entire gestation

Revised 10 CFR 20 makes this law for "declared pregnant women"

6. Reg Guide 8.29

TP-2.20
Chapter 2
Appendix

a. Instruction Concerning Risks from Occupational Radiation Exposure

- Provides instructions that should be provided to the worker concerning biological risks from occupational radiation exposure

b. Approximate risks of low dose radiation effects per 10,000 exposed/rad

TP-2.27

- Genetic-1 to 2
- Somatic (cancer)-2 to 10
- In-Utero (cancer)-2 to 10
- In-Utero (all)-10 to 100

c. Table 2-4 in 8.29 provides comparisons of radiation exposure risks with other activities

TP-2.28

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INSTRUCTOR NOTES/KEY AIDS

III. RADIATION PROTECTION STANDARDS AND GUIDES

A. Introduction

1. Section provides overview of regulations and guides for exposure to radiation and types of areas and signs commonly found at nuclear power plants
2. Chapter 3 Objectives
3. NRC employees are exempt from 10 CFR 20- must follow NRC Manual Chapter 0524
 - a. Basically same as part 20

TP-3.1

Chapter 3
Appendix

B. ALARA Concept

1. Standards, regulations and guides provide limits and controls for protection against ionizing radiation
2. All personnel should strive to maintain their exposure ALARA, far below limits

Revised 20
"should" changes
to "shall"

C. Review of 10 CFR, Part 19 - Notices, Instructions and Reports to Workers; Inspections

1. Purpose
 - a. Establishes the requirements for notices, instructions, and reports by licensees to workers participating in licensed activities and options available for workers to contact the NRC

TP-3.2

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NOTES/KEY AIDS**

2. Licensee's responsibilities

a. 19.11 Posting of Notices to Workers:

TP-3.3

- Licensee must provide:
 - Current copies of 10 CFR 19 and 20
 - Applicable operating procedures for licensed activities
 - Any notices of violation and licensee responses
- Notices must appear in sufficient numbers and within 2 working days of issuance

b. 19.12 Instructions to Workers

TP-3.4

- Workers frequenting any portion of restricted areas must be kept informed of storage, transfer, protective measures, use, precautions, and radiation risks associated with the radioactive materials present

Also covered in
NRC Manual
Chapter 0524

c. 19.13 Notifications and Reports to Workers

TP-3.5

- Licensee must provide workers with exposure records annually and upon termination of work
- Also, within 30 days of request, the licensee must provide former workers with exposure records for time of employment

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3. 19.14 and 19.15 provided Regulations concerning inspections, presence of licensee representatives during inspections and consultation with workers by inspectors
 - a. IN 88-151 prohibits licensee from broadcasting arrival or progress of NRC inspectors

D. Sources of Standards and Requirements

1. NRC Manual Chapter 0524
 - a. Provides "standards" for radiation exposure of NRC employees
2. 10 CFR Part 20
 - a. Regulation for control of occupational exposures and radioactive materials by NRC licensees
3. Applicable Reg. Guides, other parts of Title 10 and Title 40 of CFR

TP-3.6

**NRC employees
visiting a site are
expected to obey
site regulatory
and administra-
tive limits**

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

E. Radiation Dose Standards for Individuals in Restricted Areas

1. Restricted area is an area in which access is restricted for purpose of controlling exposure to radiation

However, the only legal limit is 0524. If performance of your job requires longer stay time than allowed by a site admin limit, you should inform the site
- Radiation Supervisor that you will be exceeding the admin limits
10 CFR 20.101
NRC 0524,
Part 2A

2. Dose Limits

TP-3.7

- a. Whole Body (head and trunk, active blood forming organs, lens of eye, or gonads)
 - 1.25 rem/quarter
 - Increased to 3.0 rem/quarter with complete form 4
 - Must have documented accumulated occupational exposure <5 (N-18) rem to use 3.0 rem/qtr limit
 - N = age of individual

Only penetrating radiation
 β , γ

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b. Extremities - hands, forearms, feet and ankles

- 18.75 rem/quarter

c. Skin of the whole body

- 7.5 rem/quarter

d. Limits for individuals under 18 years of age are 10% (1/10)

e. Internal Exposures

Both penetrating and non-penetrating radiations considered

10 CFR 20.103
NRC 0524, Part 2C

- Limited by controlling amount of radioactive material inhaled, ingested or absorbed into body
- Inhalation controlled by limiting product of:

Airborne Concentration X Exposure Time
(Maximum Permissible Concentrations) (hours)

MPC-hrs

- Uptake limits - 520 MPC - hrs/quarter
 - MPC - hr based on amount of internal radioactivity necessary to exceed maximum permissible dose standards for whole body
 - Estimated risk of one MPC - hr is \approx 2.5 mrem external exposure to whole body

Based on continuous exposure for 40 hours per week for 13 weeks (1 quarter)

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- Administrative Limits
 - Used by licensees to control dose for periods less than a quarter and to support ALARA
 - Examples: 50 mrem/day
100 mrem/week
- Personnel Monitoring
 - Required for individuals likely to exceed 25% of limits

Quarterly administration limits may be less than limits stated in NRC 0524 and 10 CFR 20

F. Posting Requirements

1. Unrestricted Area

10 CFR
20.105-20.204
NRC 0524
Parts 2C, 3B,
3C

- a. Area which is maintained with radiation levels under 2 mrem in 1 hour or 100 mrem in 7 consecutive days
- b. No posting requirements

500 mrem per year implied limit

2. General Posting Requirements for areas restricted for purpose of controlling radiation

- a. Radiation symbol in magenta or purple on yellow background
- b. Other appropriate information aiding in minimizing exposure may be provided on or near signs

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NOTES/KEY AIDS**

- | | |
|---|---------|
| 3. Restricted Area | TP-3.8 |
| a. Must be posted if individual is likely to receive dose in <u>excess</u> of 2 mrem in any 1 hour or 100 mrem in seven consecutive days | |
| 4. Radiation Area | TP-3.9 |
| a. Criteria | |
| • Any area where the dose in 1 hour to a major portion of the whole body could result in 5 mrem or, in five consecutive days, in excess of 100 mrem | |
| b. Radiation Symbol
+
CAUTION, (OR DANGER)
RADIATION AREA | |
| c. Example | TP-3.10 |
| 5. High Radiation Area | TP-3.11 |
| a. Criteria | |
| • Any area where the dose to major portions of the body in 1 hour could be in excess of 100 mrem | |
| b. Radiation Symbol
+
CAUTION, (or DANGER)
HIGH RADIATION AREA | |
| c. Example | TP-3.12 |

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6. Airborne Radioactivity Area

TP-3.13

a. Criteria

- Any area where radioactive materials exist in concentrations in excess of amounts listed in Appendix B, Table 1 or any area where airborne radioactive material exist in concentrations which, averaged over time/week individual is in area, exceed 25% amounts specified in Appendix B, Table 1

b. Radiation Symbol

+

**CAUTION, (or DANGER)
AIRBORNE RADIOACTIVITY AREA**

c. Example

TP-3.14

7. Radioactive Material(s)

TP-3.15

a. Criteria

- Area or room in which there is used or stored an amount of licensed materials exceeding 10 times the quantity specified in Appendix C, or 100 times the quantities given for U or Th

b. Posting

- **CAUTION, (or DANGER)
RADIOACTIVE MATERIAL(S)**

c. Example

TP-3.16

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8. Other Areas and Postings

a. Contamination Area (Zone)

TP-3.17

- Contains loose contamination
- Protective clothing required for entry

b. Multiple postings

TP-3.18

c. Part 50 of 10 CFR Appendix I (ALARA) limits annual doses in unrestricted areas from effluents or emissions to the following:

- Limit per reactor from liquid effluents:
 - 3 mrem/yr total body or
 - 10 mrem/yr any organ
- Limit per reactor from gaseous effluent submersion:
 - 10 mrad/yr from gamma or
 - 20 mrad/yr from beta
- External dose from gaseous effluents:
 - 5 mrem/yr to the total body or
 - 15 mrem/yr to the skin
- Limit per reactor from iodines and particulate released to the atmosphere:
 - 15 mrem/yr to any organ

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- d. Part 190 of 40 CFR (EPA) limits whole body dose in unrestricted area from fuel cycle operations:

- 25 mrem/year

- e. Part 71 of 10 CFR (Transportation) has variety of limits based on shipping class and accessibility. General limits, not to exceed

TP-3.19

- 200 mrem/hr on contact 10 mrem/hr at 1 meter

G. Recommendations Concerning Emergency Exposure

1. NRC Manual Chapter 0524 Part 6

Not in 10
CFR 20

2. Maximum permissible dose values:

TP-3.20

- a. Saving Human Life - 75 rem
- b. Recovery of Deceased Victims - 12 rem
- c. Protection of Health and Property - 25 rem

H. Recommendations for Prenatal Radiation Exposure

1. NCRP recommends maximum dose equivalent to fetus of 0.5 rem during entire gestation
2. Reg Guide 8.13 provides guidance

TP-3.21

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I. The "Revised" 10 CFR Part 20

1. "Old" Part 20 revised to incorporate recommendations specified in ICRP publications 26 and 30
 - a. After 12 years of deliberation, July 30, 1990 USNRC approved revised Part 20 as "final rule"
2. USNRC and agreement state licensees must be in full compliance by January 1, 1994
3. Dose limit changes under Revised Part 20
 - a. Whole Body (total Effective Dose Equivalent) - 5 rem/year
 - b. Lens of eyes (Measured at a depth of .3 cm) - 15 rem/year
 - c. Hands, forearms, feet and ankles (measured at a depth of .007 cm) - 50 rem/year
 - d. Skin of whole body (Measured at a depth of .007 cm) - 50 rem/year
 - e. Internal dose - no separate limit, part of whole body dose
 - f. Organ dose equivalent (External plus internal dose) - 50 rem/year

Describe
"agreement
state"

TP-3.22

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**INSTRUCTOR
NOTES/KEY AIDS**

**4. Posting Requirement Changes Under the Revised
Part 20**

TP-3.23

a. Radiation Area

- Radiation symbol
+
CAUTION, (or DANGER)
RADIATION AREA

- Criteria

Area accessible to individuals in which radiation level could result in a dose equivalent in excess of 0.005 rem in 1 hour at 30 cm from the source or surface the radiation penetrates

Specifies distance from source and eliminates weekly limit

b. High Radiation Area

- Radiation symbol
+
CAUTION, (or DANGER)
HIGH RADIATION
AREA

- Criteria

Area accessible to individuals in which radiation levels could result in a dose equivalent in excess of 0.1 rem in 1 hour at 30 cm from the source or surface the radiation penetrates

Specifies distance from source

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c. Very High Radiation Area

TP-3.23 (cont'd)

- Radiation symbol
+
GRAVE DANGER,
VERY HIGH
RADIATION AREA
- Criteria

Areas accessible to individuals in which radiation levels could result in absorbed dose in excess of 500 rads in 1 hour at 1m from the source or surface the radiation penetrates

Not defined in
"old" Part 20

d. Airborne Radioactivity Area

- Radiation symbol
+
CAUTION, (or DANGER)
AIRBORNE
RADIOACTIVITY
AREA
- Criteria

A room, enclosure, or area in which airborne radioactive materials, composed wholly or partly of licensed material exist in concentrations..

In excess of DACs specified in Appendix B

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To degree that without respiratory protection individual could exceed in 1 week, an intake of 0.06% of the ALI or 12 DAC-hours

e. Radioactive Material(s)

TP-3.23 (cont'd)

- Radiation symbol
+
CAUTION, (or DANGER)
RADIOACTIVE
MATERIAL(S)

- Criteria

Area or room in which there is used or stored an amount of licensed material exceeding 10 times the quantity of such material specified in Appendix C

Appendix C
values were
revised

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IV. CONTROL OF RADIATION EXPOSURE

A. Introduction

1. Purpose

Section provides basic guidelines for participants in this course to maintain their radiation exposure as low as is reasonably achievable while at a nuclear power station.

2. Chapter 4 Objectives

TP-4.1

B. Sources of Radiation

Instructor should point out that due to differences in design between a PWR and a BWR, source location will differ

1. General Reactor Designs

a. Overall goal is controlled criticality

b. General arrangement

- Fuel assemblies-made of a large number of fuel rods
- Fuel rods-made up of fuel pellets in a sealed tube

Definition
Criticality:
When the number of neutrons released by fission is equal to the number of neutrons absorbed plus the number of neutrons escaping

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LESSON OUTLINE

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- Control rods-moveable assemblies of neutron absorbing material. Can be moved out of the core to increase the active volume of the core. Rapid insertion "scrams" the reactor for a quick shutdown.

Commonly cadmium, hafnium, or boron
- c. Basic Components

TP-4.2
 - Active core

TP-4.3
 - 1) Location of the fuel where the fission process takes place
 - Moderator

Only used in thermal reactors
 - 1) Material to thermalize fast neutrons

Common moderators are ordinary water, heavy water (deuterium oxide), carbon (graphite), and beryllium
 - Reflector
 - 1) Material to decrease the loss of neutrons from the core by scattering many back
 - 2) Thermal reactors
 - a) Typically use the same material as the moderator

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- 3) Other reactors
 - a) Some material to reflect without moderating the neutrons
- Heat removal system
 - 1) Coolant
 - a) Medium circulated through the core to remove the heat from fission
 - 2) Heat sink
 - a) PWR's use a steam generator to remove the heat from the coolant
 - b) Research and other reactors (such as BWR's) may use some sort of cooling towers or ponds to cool in conjunction with "condensers"
- Control systems
 - 1) Control rods
 - a) The most common method of starting and stopping the chain reaction

Coolants used have been liquid water, liquid sodium, organic compounds, gases, air, carbon dioxide, and helium

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2) Poisons

- a) Burnable poisons placed in the fuel rods
- b) Injectable poisons to shutdown the reactor

2. Major Reactor Types

a. Production reactors

- Used for the production of ^{239}Pu

b. Research reactors

- Used for materials studies on effects of the reactor core environment
- Used for potential future designs
- Large number of potential and existing designs, however, most common is "swimming pool" reactor-a water moderated and reflected reactor in a large pool of water

Found at many universities

c. Power reactors

- Nuclear reactors designed to produce electricity
- Light water reactors include:
Boiling water reactors (BWR), and

TP-4.4

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Pressurized water reactors (PWR)

TP-4.5

- Heavy water reactors are of Canadian design
- Fast breeder reactors are an experimental model in U.S.

TP-4.6

3. Fission Process

- a. Generates very high levels of gamma and neutron radiation
- b. Biological shields and other components inside containment limit radiation levels in routine work areas
 - Reactor shutdown ceases the fission process, and resulting "prompt" radiations
 - Main source of neutrons

Fission:

Nuclear fission occurs when a heavy nucleus absorbs a neutron and splits into two new nuclei with the release of large amounts of energy and neutrons

4. Fission Products and Decay

- a. Radioactive decay of fission products is a major source of radiation exposure inside containment during shutdowns and reactor refueling.

Refueling: The process of removing spent fuel, or the process of replacing/shuffling fuel elements in the core
TP-4.7

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- | | |
|---|--|
| <p>b. Activation product decay is considered the main source of radiation exposure to plant personnel</p> <p>c. Activation products can be found anywhere reactor coolant circulates, leaks, or is processed</p> <p>d. Fission products are found in the reactor coolant. If defective fuel elements exist, they may have to be considered as contributors to personnel exposures</p> | <p>Activation products:
TP-4.8
Products (or objects) which have become activated by neutron absorption and are therefore radioactive</p> |
| <p>5. Steam/Turbine/Condensate Systems</p> | |
| <p>a. Radiation sources within the reactor coolant may be found in steam and condensate systems</p> <ul style="list-style-type: none">• PWR-leak from primary coolant system to secondary system may be present• BWR-The coolant becomes the steam. Much higher radiation levels are found in steam turbine systems | <p>TP-4.9</p> <p>PWR-
Pressurized
Water Reactor
BWR-Boiling
Water Reactor</p> <p>¹⁶N, high energy gamma,-major source of BWR turbine floor personnel exposure</p> |

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6. Waste Treatment Systems

a. Liquid Radwaste Treatment

- Involves the removal and concentration of activation and fission products through filtration, evaporation, ion-exchange, settling and decay
- Components involved include:
 - Catch and holding tanks
 - Ion exchangers
 - Evaporators
 - Pipe Systems (chases)

These components should be isolated or shielded due to potential high personnel exposures

b. Solid Radwaste Treatment

- Source: Liquid waste that has been processed
- Involves packaging, compacting, and handling of waste in the solid form
- Other sources: Small radioactive components, rags and associated debris
- Solid waste sources include:
 - Resins
 - Filters

TP-4.10

Classified as low level waste

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7. Spent Fuel Storage

TP-4.7

TP-4.8

a. Pools

- Used for storage of spent fuel and other tools and reactor components
- Many feet of water used for reducing the exposure level in the general vicinity of the pool
- Sources of spent fuel storage personnel exposures include:
 - Fuel assemblies
 - Activated components
 - Stored materials
 - Fragments
 - Crud
- Factors that may contribute to personnel exposures around spent fuel storage areas include:
 - Radiation streaming
 - Flotation
 - Snagging
 - Equipment movement

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b. Dry Storage

- Heavily shielded containers are being approved for the storage of older fuel. These containers are made up of concrete and steel.
- Radiation levels around these containers are expected to be relatively low.

TP-4.11

TP-4.12

8. Examples of Other Sources

1. Other sources of radiation include:

- Penetrations through walls and shields
- Incore instruments
- Small reactor components
- Transfer tubes/spent fuel movement
- Calibration operations (including radioactive sources)
- Reactor coolant and waste processing samples
- Plant Operations

Radiation levels
vary with plant
operating
stations

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B. Control of External Radiation Exposure

1. Time

TP-4.13

- a. Minimize the length of time exposed to radiation source

Discuss methods

- Pre-job planning
- Pre-job briefings

- b. Calculate and remember the "stay time" prior to entering the radiation or high radiation areas

Discuss the concept of "stay time"
TP-4.14

2. Distance

TP-4.15

- a. Maximize the distance from the radiation source

Discuss methods

- Pre-job review of area
- Knowledge of radiation source locations
- Pre-job discussion with HP's
- Don't wander into areas of unknown dose rates or conditions

- b. Radiation exposure varies inversely as the square of the distance from a small source

Inverse square law

- Example: Double the distance, exposure rate decreases by a factor of 4

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- c. Radiation exposure decreases by a factor of 2 if the source is large when compared to the distance

- Example: If distance is doubled, the rate will decrease by a factor of 2

3. Shielding

TP 4-16

- a. Keep as much shielding between you and the radiation source as possible

Examples:

- Use existing shielding
 - Pre-job briefings
 - Pre-job planning

- b. Use available components as shielding when possible

TP-4.17

- c. Avoid being in the "line of sight" of radioactive sources

- d. Gamma radiation is the main contributor to radiation dose received by personnel at nuclear power plants

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C. Contamination Control

- 1. Contamination: Radioactive material in an unwanted location**
 - a. Controlled to:**
 - Limit external exposure
 - Prevent internal exposure
 - Reduce the size of the areas requiring special controls
 - Reduce radioactive waste processing
 - b. Benefits of minimizing contamination:**
 - Further reduce exposures
 - Minimize internal depositions
 - Ease of access into areas
 - Ease of egress out of areas
 - Minimize protective clothing requirements
 - c. The prevention or limiting of intake is important to keeping total dose ALARA**

TP-4.18

**Instructor should
ask for other
benefits**

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D. Control of Internal Radiation Exposure

1. Introduction

- a. The majority of contamination in power plants results from leaking activation products

Reactor coolant system during maintenance evolutions

2. Contamination forms

a. Solid - fine particles

- Hot particles or "fleas" - (special case) - very small particles with high activity
- Can settle on surfaces or remain airborne

If a hot particle is on the skin, the limit is 75 $\mu\text{Ci-hours}$; if it is not on the skin, the skin limit applies

b. Liquid

- Exists due to leaks and/or spills
- May become dry (solid)

c. Gaseous

- Result from gases produced in reactor

Example I^{131}

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3. Categories and Detection

a. Personnel contamination: any form of radioactive contamination on personnel (including skin contamination)

- Normally detected by a sensitive GM detector such as frisker, personnel monitor, or portal monitor

TP-4.19
TP-4.20
TP-4.21

b. Categories

- Fixed
- Loose-can be inhaled, ingested, or deposited on skin
- Airborne-can be inhaled, ingested

- Licensees have site-specific limits

c. Detection

- Direct surveys detect fixed
- Smears (swipes) detect loose contamination and are counted using a sensitive GM detector
- Air sampling detects airborne contamination and is usually counted in a laboratory

Normally 100 cm² in the shape of an "S"

TP-4.22

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d. Action Levels

- Depend on type, location and area use
- Depend on licensee procedures
- Types include:

Personnel-any detectable 50-100 cpm
above background

Removable (Beta/Gamma)-1000
dpm/100 cm²

Removable (Alpha)-20 dpm/100 cm²

TP-4.23
100 cpm = 1000
dpm when
instrument
efficiency is 10
percent

4. Contamination control

a. Primary purpose: Reduces the risk of
personnel contamination

b. Examples of controls:

- Engineering controls such as
controlled/filtered ventilation zones,
HEPA filters, catch trays
- Housekeeping throughout the facility
- Conduct routine maintenance to stop
leaks
- Post and control contaminated areas

TP-4.24

TP-4.25
Special attention
paid to RCA's
where
maintenance
work is
performed

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- Minimize the number of people entering contaminated areas
 - Requiring/conducting a whole body survey upon exiting a contaminated area
 - c. Controls implemented by individuals include:
 - Entering contaminated areas only when necessary/authorized
 - Proper use of PC's
 - Proper use of respirators
 - Avoid high contamination levels as practicable
 - Avoid use of synthetic clothing
 - Avoid floor drains, areas under open stairways
 - Avoid control boundaries and points
 - Complete a whole body survey upon exiting a contaminated area
5. Airborne Contamination Control (MPC-Hrs)
- a. Control of personnel exposure to airborne radioactivity is accomplished by:
 - Limiting the exposure time and airborne concentrations (MPC's)

Due to affinity
for statically-
charged particles

TP-4.26
TP-4.27

MPC-Hrs

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b. Accomplished by:

- Utilizing engineering controls such as filtered ventilation systems
- Calculating estimated MPC-Hrs prior to entry
- Taking all reasonable action to minimize exposure
- Use of respirators

TP-4.28
Must be
respirator
qualified

E. Exposure Monitoring

1. Thermo Luminescent Dosimeters (TLD's)

- a. Normally required to be worn when entering a radiation area or controlled area
- b. Monitors whole body exposure
- c. Normally worn on upper front torso between neck and waist
 - Multiple/special TLD's may be required- monitor other body locations, extremity and skin exposure
- d. Periodic and special (as needed) processing provides exposure data
- e. Film badges may be used instead of TLD's

Review 10 CFR
20, NRC 0524
criteria for
assigning
personnel
monitoring
devices

Define
extremities

Periodic means
every month.
Special means
high dose rate
jobs, lost
dosimetry

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2. Pocket dosimeters
 - a. Used for real-time monitoring
 - b. Check frequently (minimum every 30 minutes)
 - c. Used to update exposure record and control exposure until TLD is processed
 - d. Should not be abused
 - e. If dropped should be read. If off-scale notify HP
 - f. Should not be taken apart
 3. Digital/Alarming Dosimeters
 - a. Used for monitoring and controlling exposures
 - b. Used inside high radiation areas
 - c. Also known as "chirpers"
 4. Other monitoring
 - a. Frisking
 - b. Other techniques
 - c. Identify/quantify exposure
 - d. Air sample results
 - e. Exposure time determination
- equipment, etc.
Also known as
Self Reading
Dosimeters (SRD's) or
Pocket Ion
Chambers
(PIC's)
- i.e., dropped,
submerged in
liquids, etc.

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F. Radiation Work Permit

TP-4.29

1. Normally required for entry into controlled areas
2. Standby RWP's may be used
3. Special RWP's are required depending on the job(s) to be performed
4. Serve the following functions:
 - a. Specifies general work information
 - b. Maps out the radiological hazards
 - c. Specifies personnel instructions
 - d. Specifies dosimetry requirements
 - e. Specifies dress out requirements
 - f. Specifies respiratory protection requirements
 - g. Specifies monitoring requirements
 - h. Specifies equipment (if any) which is needed to complete work
 - i. Establishes radiological/contamination limits associated with a specific job
 - j. Specifies other requirements
 - k. Provides special instructions (as required)

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5. Adherence to the RWP:
- a. Controls contamination
 - Protective apparel
 - Monitoring requirements
 - b. Minimizes exposures
 - Administrative dose limits per entry
 - Protective apparel
 - Respiratory protection equipment
 - Personnel monitoring requirements
 - c. Increases job efficiency
- G. Exposure Control Cards (Dose Cards)
- 1. Used for daily accounting of exposure
 - 2. Used in conjunction with RWP's
 - 3. Used for evaluating ALARA compliance
 - 4. Each individual is responsible for accuracy and completeness

Imposed by
licensee

Review the
RWP with
attendees

TP-4.30
and
TP-4.31

Newer systems
may use
computer
software

Instructor
Review Dose
Cards using TP's

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H. Surveys

TP-4.32

1. Individuals must be able to view and understand
2. Ask HP or escort for clarification (if needed)
3. May be attached to an RWP
4. Note areas of high radiation/contamination levels
5. Not areas of low radiation/contamination levels
6. Identify "hot spots" and "low-dose" waiting areas

Note:
"ALARA Areas"
"Low Dose
Areas"
Some licensees
post these areas

7. Purpose of performing surveys
 - a. Establishing stay times
 - b. Identify need for radiation shielding
 - c. Identify radiation, high radiation, and very high radiation areas
8. All reported results must be accurate or else problems such as overexposure or unplanned exposure may result

A survey is a study to (1) find the radiation or contamination level of specific objects or locations within an area of interest;
(2) locate regions of higher than average intensity; i.e., hot spots

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9. Specific types of surveys/Radiation surveys can be done on either a routine basis or to determine specific conditions

a. Routine surveys

- Radiation Area surveys
- High Radiation Area surveys
- Hot Spot surveys
- General Area surveys

Generally
occupied work
areas

b. Surveys to determine specific conditions

- Job coverage (work area) surveys

c. Radiation Area surveys

- Establishes point at which a radiation area begins
- Establishes extent of radiation area

d. High Radiation and Very High Radiation Area surveys

- Establishes boundary
- Establishes extent

Review
definition of
High and Very
High Radiation
Areas

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e. Hot Spot surveys

- Locates points on components where radiation levels exceed general area radiation levels by a specified amount

Usually about four times the general area radiation level

f. General Area surveys

- Performed to monitor levels of background radiation throughout a site

Background radiation is the steady level of radiation in the environment

g. Work Area surveys

- A radiation survey in work areas throughout the site to verify protection factors that are important to personnel working in those areas
- Specific job coverage situations

For on-going or frequently used work areas

I. As Low As Reasonably Achievable (ALARA)

1. Acronym for As Low As Reasonably Achievable
2. Any amount of radiation exposure may cause effects
3. Maintaining exposures ALARA will minimize the potential for long term effects
4. What is reasonable?

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5. Goals

Each licensee
sets its own
goals

- a. Each individual as well as licensee should set goals of maximum exposure for planned work
- b. Setting of aggressive goals and striving to meet or exceed will result in lower overall exposures
- c. Lower exposures reduce risk

6. ALARA Responsibility

- a. It is the responsibility of each employee to maintain his/her own dose as low as reasonable achievable

7. ALARA Procedures

- a. Good Practices/Common Sense
 - Keep your mind on the business at hand
 - Distractions are hazardous in themselves, even more so in a radiological hazard area
 - Communicate with HP personnel

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LESSON OUTLINE

**INSTRUCTOR
NOTES/KEY AIDS**

- b. Follow directions
 - Follow radiological instructions
 - Adhere to radiological and safety postings
 - Don't just look at radiological signs, understand the implications before you enter an area
 - c. Familiarize yourself with work area layout(s) prior to starting job
 - d. Obtain all of the tools you will need prior to starting job
 - e. Review radiological condition of area(s)
 - f. Identify general location of radiation source(s) when entering work area(s)
 - g. Do not linger in radiation areas. Retreat to low dose area(s) when the job is completed
8. Reg. Guide 8.8, "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations will be As Low As Reasonably Achievable"
- a. Provides information relevant to attaining goals and objectives for planning, designing, constructing, operating, and decommissioning a light water reactor nuclear power station to meet the criterion that personnel exposures be ALARA.

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LESSON OUTLINE

**INSTRUCTOR
NOTES/KEY AIDS**

- b. Goals/objectives presented should be used for all nuclear power stations
- c. Revision 3, 1978
- d. Provides programmatic guidance for ensuring exposures are ALARA

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

V. INSTRUMENTATION

A. Introduction

1. Purpose

Provide a brief overview of instruments used to detect and measure radiation levels

2. Chapter 5 Objectives

TP-5.1

B. Measuring and Detecting Radiation

1. Detecting radiation is the act of determining in real time whether radiation is present or not
2. Measurement is the act of determining how much is or was present (if any)

C. Dosimetry

1. Subtopic of instrumentation.
2. Special devices are used to measure the amount of radiation to which an individual has been exposed and this information is used to ensure compliance with federally imposed dose limits and to maintain an historical record of the individual's accumulated radiation dose
3. External Dosimetry
 - a. External dosimetry is action of determining the amount of radiation dose received by an individual from sources located outside the body

TP-5.2

TP-5.3

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

- b. Useful for monitoring doses from penetrating radiation such as x-rays, gamma rays and neutrons
- c. Also possible to monitor the dose to the skin surface from non-penetrating radiation such as beta
- d. Alpha is of no concern to external dosimetry
 - alpha particles do not have sufficient energy to reach vital tissue if incident on the surface of the body

4. Internal Dosimetry

- a. Internal dosimetry is action of determining the amount of radiation dose received by an individual from radiation sources that have been taken into the body
- b. The radiation emitted by the material exposes vital internal organs
- c. Relative hazards are directly opposite to those from external sources in terms of the Linear Energy Transfer of the radiation of interest
- d. Alpha particles deposit all of their energy in vital tissues and are thus the most hazardous
- e. Penetrating x-rays and gamma rays can easily escape and thus deposit only a small fraction of their energy in vital organs

TP-5.4

α
Cannot escape
from body

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INSTRUCTOR NOTES/KEY AIDS

- f. Betas are both an external and internal hazard since
 - They have enough energy to penetrate the sensitive skin tissues from the outside
 - Expose vital tissues from the inside
- g. Neutrons are not considered an internal hazard
 - Few radioactive materials spontaneously emit neutrons
- h. Internal dosimetry will be further discussed in the section on Bioassay

This section will deal exclusively with external dosimetry sometimes called personnel dosimetry

Note: During the following instrument descriptions, the instructor demonstrates actual use of sample instruments.

D. Personnel Dosimeters

- 1. Three types
 - a. Pocket dosimeters
 - b. Film dosimeters
 - c. Thermoluminescent dosimeters (TLD's)

TP-5.5

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

E. Pocket Dosimeters

TP-5.6

1. Used for the dual purpose of detecting the dose as it is being received in real time and measuring how much was received

2. Direct Reading Dosimeters - usually of the pencil type design.

TP-5.7

- a. Individual reads dosimeter by peering through it like a mini telescope.
- b. Dose is indicated by the "hairline" on the scale.

3. Principles of Operation

- a. Hairline is initially set at zero by placing dosimeter in a charging device which distributes similar charges on the moving and fixed wire loops
- b. Similar charges cause mobile wire loop to be repelled and when fully charged, loop appears to be super imposed over the zero position on the scale
- c. As dosimeter is exposed to radiation, the ions produced dissipate the charge causing the repulsion between the loops to decrease
 - As the repulsion decreases, the mobile loop moves across the scale

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INSTRUCTOR NOTES/KEY AIDS

4. Indirect Reading

- a. Must be read with a charger/reader
- b. Workers are unable to monitor their dose as it is being received.
- c. Can be useful in situations where a result is required sooner than can be provided by either film dosimetry or TLD

5. Digital Alarming Dosimeters (DAD)

TP-5.8

- a. Indicate the accumulated dose using a digital display.
- b. Worker presses a button to see their current dose.
- c. Major advantage
 - Emit an audible signal (beep) when a certain amount of radiation is detected.
 - Some can preset alarm to trigger at some accumulated dose value
 - e., 100 mrem
 - Some models have a second alarm which can be set at a predetermined dose rate
 - e., 1000 mrem/hr

Some direct reading dosimeters have LED displays which are normally blank. Worker can perform task knowing that when alarm sounds they can leave before exceeding limits

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5. Pocket Dosimetry Characteristics

a. Range - Pockets have a specified range over which they are effective

TP-5.9

- Important to know approximate maximum dose you are likely to receive to be able to select a dosimeter with the appropriate range
- As an example, a 0 to 20 rem pencil dosimeter won't help you to measure a 100 millirem dose
- Pocket dosimeter should read zero before being used

Not critical if there is a small dose already on it, as long as it's noted at the time of issue

b. Fragility

- Subject to false readings
- If you drop them they can move up or down scale
- Should always be read in the proper orientation (right side up and not upside down or standing on end)

Use a filament to indicate dose- they are fragile

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INSTRUCTOR NOTES/KEY AIDS

c. Leakage

- Can be affected by charge leakage
- A leaking charge will always result in an upscale movement which will result in a false positive reading
- If there is a question about the proper operation of the dosimeter, retreat to a low-dose area and contact the radiological controls technician

Since based on electrical principles

d. Environment

- Can be susceptible to environmental conditions such as humidity

F. Film Badges

TP-5.10

1. Device used for measuring beta, gamma, and neutron radiation by means of a piece of radiation sensitive film similar to x-ray film or photographic film
2. Radiation striking the film causes atomic and molecular changes which when chemically developed cause the film to be darkened
 - a. Black areas means exposed
 - b. Clear areas means not exposed

The density of the dark areas indicate how much radiation was received

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

3. Typically constructed of plastic to allow gamma radiation to penetrate to the film inside
 - a. Also use a small opening, called a window, to allow a section of the film to be exposed to both beta and gamma radiation
4. Major advantage
 - a. Produces a permanent image of the radiation exposure which can be kept almost indefinitely
5. Film is sensitive to environmental conditions
 - a. Heat will cause film to fog
 - May overestimate the dose
 - b. Film will fade if not developed soon after use.
 - May underestimate the dose
6. Film also has a range problem
 - a. As dose goes higher the film gets darker but at some point it gets as dark as it will ever get
 - b. After this point it will not respond to additional dose and will underestimate the amount of dose received

The range at which this occurs is generally at a very high total dose

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

G. Thermoluminescent Dosimeters (TLD's)

1. TLD's have virtually replaced film as method of measuring beta and gamma radiation dose
2. TLD's are crystals which have the ability to store information indicating how much radiation they were exposed to
 - a. Information is in form of electrons which move to higher energy levels when exposed to radiation
 - b. Electrons remain trapped in these levels until the crystal is heated
 - Heat causes the electrons to fall back to their initial levels and when they do, stored energy in the form of light is emitted
 - Amount of light emitted is proportional to the amount of energy initially absorbed by the crystal
 - c. Substances commonly used as TLD material
 - Lithium fluoride (LiF)
 - Calcium fluoride (CaF₂).

TP-5.11

Can be of almost any form or shape

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INSTRUCTOR NOTES/KEY AIDS

- d. Badges have more than one chip and various overlying filters to assist in identifying the energy and type of radiation which caused the exposure

- Commercially available TLD's are designed to simulate the skin, lens of the eye and whole body

Discuss
measurement
depths and
density
thicknesses

- e. TLD's do not provide a permanent record

- When a TLD is heated the results are transferred to either a printout or computer database

H. General Dosimetry Rules

TP-5.12

1. Don't forget to wear one when it is required
2. Don't forget to turn it in for evaluation when you exit the radiation area, and
3. If you should lose your dosimeter while in a radiation area, or if your pocket dosimeter reads off scale, *LEAVE THE AREA*.
 - a. As you leave, notify anyone in the area, particularly if your pocket dosimeter is off scale
 - They may wish to check to see if their dosimeter is off scale

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

I. Instruments

1. Survey Meters

- a. Typically portable radiation detection instruments designed to be used in the field, under less than ideal conditions TP-5.13
- b. Typically have an accuracy of $\pm 10\text{-}20\%$
- c. Principle use is to help evaluate the current situation and make an intelligent decision based on the results
- d. Basic Operating Principle
 - Radiation being detected or measured interacts with the atoms of a substance (gas, liquid or solid) and ionizes the material (creates free electrons and positive ions)
 - In some cases the ions are collected directly (gas filled and solid state detectors)
 - In others the light emitted by the atoms as they return to normal is measured (TLD's) or the light emitted is used to generate photoelectrons which are collected (scintillation)

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LESSON OUTLINE

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e. Check Operability

TP-5.14

- Calibration - Check to see if the instrument is past due on its calibration.
- Range - Will the instrument cover the radiation or contamination levels expected?
- Physical condition - Does the instrument have obvious damage?
- Allow the instrument to adjust to differences in environmental conditions, such as significant difference in temperature, by turning it on and giving it time for the readings to settle out
- Perform a battery check by selecting the battery test option

If past due do not use instrument

Keep the instrument in this mode for about a minute to ensure that the batteries are not close to expiring

- Response to radiation - Expose the instrument to a source of radiation of sufficient strength to get a response

If it does not respond or responds incorrectly, do not use the instrument

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INSTRUCTOR NOTES/KEY AIDS

f. Check Applicability

TP-5.15

- Types of radiation - Will the instrument detect the type of radiation (alpha, beta, gamma, neutron and/or x-ray) that is of interest?
- Energy detected - Most instruments have a low energy cut-off so that they will not detect radiation below a specified energy. If that energy cut-off is above the energy of the radiation of interest then the instrument will not respond properly
- Energy response - ideally an instrument should have a flat response. If an instrument does not have a flat energy response then the under or over response must be compensated for, perhaps by applying a correction factor
- Response time - indicates how fast the display tells the actual radiation level
- For most instruments the response is very quick. Some instruments have a variable response
- "Do I know how to use it?" - this is the most important question. Ensure that you know how to use the instrument prior to entering a radiation field

A neutron flux meter set up for fast neutrons will not adequately detect or measure thermal neutrons

Technically, the response time is that amount of time required to indicate 90% of the actual level

A fast response gives less accuracy than a slow response

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g. Features - Beta discrimination

- Many Instruments have a movable beta shield
- This is simply a thick cover for the detector which, when used, prevents the betas from being detected
- With the beta shield closed the instrument is only detecting penetrating gamma radiation
- With the beta shield open, the instrument detects both beta and gamma radiations
- By subtracting the two values and applying a correction factor the presence and relative magnitude of beta radiation can be determined

TP-5.16
TP-5.17

h. Battery Life - is typically over 100 hours but is affected by the type of batteries and temperature

Radiofrequency - from a RF transmitter can cause false positive and erratic readings

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

- j. Electrical fields - in the form of static electricity can cause false positive readings
- k. Sensitivity - to a particulate radiation such as alpha and beta is sometimes given as a percent
 - Sensitivity indicates what percentage of the particles actually emitted will be detected by the instrument

May be referred to as "efficiency"

2. GM Instruments

TP-5.18

- a. Typically used to detect beta and gamma radiation
- b. Used to check objects and personnel for contamination by frisking
- c. Instrument scales are usually in counts per minute (cpm)
- d. Some instruments have scales in mR/hr. Since GM instruments do not have a flat energy response these instruments are only accurate at the energy at which they were calibrated
- e. The principle advantage of a GM detector is sensitivity and rapid response

TP-5.19

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**INSTRUCTOR
NOTES/KEY AIDS**

- f. Frisker is a portable GM survey meter such as an Eberline E-520 or RM-14 TP-5.20

- The probe is connected to the meter by a cable and is commonly used for personnel contamination monitoring

- g. Handheld is the other common type of GM survey meter likely to be encountered

- A typical model is the Xetex 305B where detector is part of the instrument and is small enough to fit in the average shirt pocket TP-5.21

3. Ionization chamber TP-5.22

- a. Ionization chambers are typically air filled

- b. Ionization chambers operate at a lower voltage than GM detectors

- Produces less ion-electron pairs
- Ionization chambers collect all ion pairs created by the radiation and are therefore very accurate

- c. Ionization chambers have a flat energy response and yield accurate readings over a wide range of gamma and beta energies

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- d. The Eberline RO-2 and RO-2A are typical of ionization chambers that are commercially available
 - The difference between the two models is that the ranges of the RO-2A are a factor of 10 greater than the RO-2
- 4. Teletector - is essentially a high range instrument for reevaluating radiation levels without unnecessarily exposing the individual
 - a. Has a detector at the end of a pole that can be extended up to 15 feet in some models
- 5. Displays come in two varieties, analog and digital
 - a. Both communicate the same information and respond at the same speed
 - b. Human perception causes the analog display to appear faster and more accurate even though both are reacting identically to fluctuations in radiation levels

TP-5.23

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

VI. BIOASSAY

A. Introduction

1. Purpose

Provide a brief overview of the principles of bioassay including whole body counting and biological sampling to evaluate internal contamination.

B. Chapter 6 Objectives

TP-6.1

- 1. Measurement of radioactive material in the body**
- 2. Also called internal dosimetry**

C. Bioassay Techniques/Categories

1. Bioassay may be accomplished by:

a. Whole body counting

- Also known as in-vivo measurements**
- Method of determining the amount of radioactive material physically present in the body by detecting the penetrating radiation emitted from inside the body**

TP-6.2

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

- b. Biological sampling
 - Also known as in-vitro measurement TP-6.3
 - Method of determining how much radioactive material is present in a sample collected from the body (e.g., urine) and then calculating how much material is actually in the body based on how much was in the sample
- 2. Basic categories of bioassay TP-6.4
 - a. Baseline
 - Performed to determine if an individual has previously had material deposited internally
 - b. Routine
 - Performed at regular intervals to determine if any radioactive material is being taken into the body during routine work activities
 - c. Diagnostic
 - Done when there is a known or suspected internal exposure

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LESSON OUTLINE

**INSTRUCTOR
NOTES/KEY AIDS**

D. External/Internal Exposure

- | | |
|--|--------|
| 1. Basic methods of protection from external sources | TP-6.5 |
| a. Time | |
| b. Distance | |
| c. Shielding | |
| 2. Basic methods of protection from internal sources | TP-6.6 |
| a. Once inside there is no method of completely eliminating the material quickly | |
| b. The best protection is to not let the radioactive material get inside. This can be accomplished by: | |
| • Using engineering controls | |
| • Obeying postings | |
| • Wearing protective clothing | |
| • Using respirators | |
| • Containing the materials | |
| • Not working in a contaminated area with open wounds | |

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

3. Intakes

TP-6.7

- a. Radioactive material can get inside the body by several pathways:
 - Inhalation
 - Ingestion
 - Absorption
 - Puncture
- b. Of the four pathways, inhalation is the most common

4. Distribution

- a. Material within the body moves around based on solubility or transportability

b. Soluble

TP-6.8

- Means that a substance is easily distributed in water or bodily fluids such as blood and urine

c. Transportable

TP-6.9

- Means that a substance is easily transferred (without being dissolved) from one organ system to another

(e.g., from the lungs to the GI system)

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

5. Uptake

- a. Dependent on chemical, not radiological properties of the substance
- b. The fraction of the intake that enters the blood stream or is deposited in a critical organ

TP-6.10

6. Critical Organ

Revise 10 CFR
20

- a. That body site whose damage by radiation will result in the greatest harm to the individual
- b. Each radionuclide may have a different critical organ
 - Cs-137 - Muscle
 - Sr- 90 - Bone
 - I-131 - Thyroid

TP-6.11

TP-6.12

E. Whole Body Counting

- 1. Direct measurement of internal radioactivity using organ counters or whole body counters
- 2. Individual may be evaluated:
 - a. Standing
 - b. Sitting
 - c. Lying down

TP-6.13

TP-6.14

TP-6.15

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

3. The amount of shielding will be a major contributor to the smallest amount of radioactive material detectable.

4. The system may be:

- a. Open
- b. Partially shielded
- c. Fully shielded

5. Counting Time

- a. May vary from 1 minute to 30 minutes or longer
- b. The longer the count, the smaller the amount of material detectable

For low level systems pre-World War II battleship steel is used because it was manufactured prior to nuclear weapons testing and Co-60 tracers in blast furnaces

Sometimes called the minimum detectable activity (MDA)

6. Detectors

- a. The detectors typically used for whole body counters are
 - Sodium iodide (high efficiency but low resolution), germanium (low efficiency but high resolution)

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**INSTRUCTOR
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- b. Efficiency
 - The ability to detect all of the radiation being emitted
- c. Resolution
 - The ability to distinguish between gamma rays having different energies
- 7. Organ counter
 - a. Basically the same as a whole body counter except that the detectors are focused on specific organs where the radioactive material is likely to be located
- 8. Specificity
 - a. Whole body counters can not distinguish the origin of the radiation
 - b. External skin contamination will result in an over estimation of the amount of radioactive material within the body
- 9. Advantages/Disadvantages
 - a. Advantages of whole body counting
 - Provides a rapid assessment of internal contamination
 - Can localize the site of deposition

TP-6.16

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INSTRUCTOR NOTES/KEY AIDS

- Does not depend on the solubility or excretion rate
- The range of error is usually low
- b. Disadvantages of whole body counting
 - Sensitive to external contamination
 - Primarily limited to gamma emitters above 100 KeV
 - Requires elaborate, complex and expensive equipment
 - Gives no information on time that the intake occurred

F. Biological Sampling

1. Biological Elimination

- a. Radioactive material may exit the body via several pathways in conjunction with these substances:

TP-6.17

- Urine
- Breath
- Sputum
- Blood

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INSTRUCTOR NOTES/KEY AIDS

- Nasal Mucous
 - Feces
 - Sweat
 - b. The rate at which radioactive material is removed by the body is very important and must be predictable
2. Half-life
- a. Radiological Half-Life TP-6.18
 - The length of time required for half of the radioactive atoms to decay
 - b. Biological Half-Life TP-6.19
 - The length of time required for the body to eliminate one half of the material
 - c. Effective Half-Life TP-6.20
 - The combined effect of both radiological and biological half-lives
 - $T_{1/2 \text{ eff}} = \frac{T_{1/2 \text{ R}} \times T_{1/2 \text{ B}}}{T_{1/2 \text{ R}} + T_{1/2 \text{ B}}}$

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

- | | |
|---|----------------|
| <p>3. Excretion Rate</p> <p>a. Based on several factors</p> <ul style="list-style-type: none">• The material• Route of entry into the body• Time after intake• Organ in which the material is deposited• Biological factors of individual exposed <p>b. The first four factors are predictable but the final factor is unpredictable</p> <p>c. Since the individuals unique metabolism is unknown we use a "reference" or "standard" man or woman to predict the excretion rate</p> | <p>TP-6.21</p> |
| <p>4. Screening</p> <p>a. Nasal smears are one example of a screening method</p> <p>b. Not used to measure the amount of intake but can estimate the magnitude</p> | <p>TP-6.22</p> |
| <p>5. Urinalysis</p> <p>a. Urine is a common body product collected for evaluation of the intake/uptake of radioactive materials</p> <p>b. Feces in some circumstance could be a better indicator of initial intake</p> | <p>TP-6.23</p> |

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LESSON OUTLINE

**INSTRUCTOR
NOTES/KEY AIDS**

c. Advantages of urinalysis TP-6.24

- Most radionuclides are eliminated to some extent
- Alpha, beta and gamma emitters can be readily identified
- Many samples can be processed simultaneously
- Collecting urine samples has a minimum impact on worker time
- Biological sampling involves low cost

d. Disadvantages of urinalysis TP-6.25

- There is a time lag between sample collection and analysis
- There must be enough radionuclide in the sample to be detected
- Analytical procedures are time consuming
- Excretion rates vary with individuals and with time
- Insoluble particles will not be excreted in the urine
- The individual may not follow instructions for voiding the sample

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LESSON OUTLINE

**INSTRUCTOR
NOTES/KEY AIDS**

G. Dose Assessment

TP-6.26

1. The hazard of internally deposited radionuclides depends on:
 - a. Amount of material
 - b. Effective half-life
 - c. Critical Organ
 - d. Energy and type of radiation

2. Acute/Chronic Exposure

a. Acute exposure

TP-6.27

- Any intake of radioactive material resulting from a single event

b. Chronic exposure

TP-6.28

- Any intake (usually at a low rate) which occurs continuously or periodically over a long period of time

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

3. Maximum Limits

Revised with
1991 version of
10 CFR 20

a. Maximum permissible body burden (MPBB)

TP-6.29

- The amount of a radionuclide which, if inside the body, will give the maximum dose allowed by regulations to the whole body
- Currently 5 rem whole body dose

b. Maximum permissible organ burden (MPOB)

TP-6.30

- The amount of a radionuclide which, if inside the body, will give the maximum dose allowed by regulation to the critical organ
- Currently 15 rem/year to any single organ excluding bone, skin, gonads, and thyroid

Limit to skin and thyroid is 30 rem/year, limit to gonads and uniformly deposited nuclides in the body is 5 rem/year

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- c. Maximum permissible concentration (MPC)
- The MPC is based upon an MPOB that will result in a limiting dose rate after 50 years of exposure
 - That concentration of radioactive material in air which if taken into the body at the rate of 520 MPC-hrs per quarter will result in either a MPBB or MPOB

TP-6.31
See Appendix B
for values. Also
similar values for
water

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

VII. PERSONNEL DECONTAMINATION

A. Introduction

1. This section provides an understanding of the importance of personnel decontamination and the techniques used to remove contamination from personnel.

2. Chapter 7 Objectives

TP-7.1

B. Goals of Personnel Decontamination

TP-7.2

1. Reduce Exposure
2. Minimize intake of contaminants
3. Prevent contamination spread

C. Identification of Contamination

1. Personnel surveys
 - a. Whole body surveys required when exiting known or potentially contaminated areas
 - b. Spot or localized surveys when exiting areas with a low potential for contamination

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LESSON OUTLINE

**INSTRUCTOR
NOTES/KEY AIDS**

2. Monitoring Devices

- a. Hand held frisker probes
- b. Automated personnel monitors
- c. Hand and foot monitors
- d. Portal monitors

TP-7.3

TP-7.4

Show any available examples of frisking devices. Frisking units are typically set to alarm at twice background (≈ 100 counts per minute above background in low background areas).

D. Actions if contamination is detected

- 1. If unit alarms, follow site procedure

Emphasize:
**DO NOT
SPREAD
CONTAMINA-
TION**

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

2. Typical Actions

a. Notify Health Physics

b. Health Physics actions

- Additional surveys with other instruments to pinpoint contamination
- Wipe surveys to determine if contamination is removable
- Whole body counts to identify internally-deposited radionuclides

There will be some variation from site to site

These are basic actions, level of contamination will determine specific response

3. Verification of contamination will require decontamination

E. Personnel Decontamination Techniques

1. Decontamination of widespread or general contamination

a. Shower with tepid water and mild soap

- Wash to avoid spreading contamination to clean areas
- Keep contamination out of eyes, nose and mouth
- Flush with copious water, but minimize total time

TP-7.5

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

- Dry thoroughly

Drying should be accomplished by patting the skin, avoid rubbing. Explain why surface must be dry (minimize attenuation)

- Survey

- Repeat if contamination is still present

Showering maybe used 2 to 3 times if decreases are indicated

- Scrubbing with a soft bristle brush may be used

If any scrubbing device is used DO NOT break or abrade the protective skin barrier through excessive scrubbing

2. Decontamination of Localized Contamination

a. Contamination of eyes, mouth or open wound

TP-7.6

- Flush area freely with water or normal saline
- Contact physician immediately

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INSTRUCTOR NOTES/KEY AIDS

b. Nasal Contamination

- Blow nose gently several times
- Wet cotton swabs can be used to decontaminate and/or collect samples
- Other techniques for decontamination should be administered by physician

Avoid inhaling through nose

Swabs should be collected by the individual or a physician only

This may include nasal irrigation

c. Hair decontamination

- Wash hair and dry
- Survey and repeat if necessary
- Medical personnel may be required to trim hair and begin decontamination of the skin if necessary

Several washings may be necessary. Process is continued until contamination is removed or no removal is accomplished by washing.

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LESSON OUTLINE

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d. Skin decontamination

- Begin with mild soap and tepid water washing. Scrubbing should be performed carefully to not abrade the skin
- Try a mild paste such as a mixture of 50% detergent (Tide, for example) and 50% cornmeal. Commercial decontamination foams or regular shaving foam may be useful

The following list is a generalized sequence, surveys should be performed after each attempt and prior to initiating additional techniques.
TP-7.7

The previous techniques should be attempted 3 or 4 times before proceeding.

- A chemical agent such as potassium permanganate is usually the next step. Applied to the skin, it removes a small portion of the epidermis and should never be applied to the skin for greater than two minutes. After treatment, the permanganate is decolorized with a solution of sodium bisulfite and the area rinsed with water.
- Decontamination may be accomplished by sweating. Wrapping the affected area in plastic or rubber enhances sweating. Cotton or other absorbent should be used inside the plastic to collect the contamination.

Chemical decontamination should be conducted under medical supervision

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LESSON OUTLINE

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- Decontamination by waiting for the radioactivity to decay away is used when the radioactive half-life is sufficiently short to permit decontamination in about 30 minutes, and
- Swabs, wipes, adsorbents and decontamination residues should be analyzed for radioactivity identification.

F. Decontamination of clothing

1. Minimize chance of contamination

- a. Avoid polyester (synthetic) clothing
- b. Avoid soft, spongy-soled shoes

Particulates are electrostatically attracted to the clothes

2. Decontamination Techniques

- a. Radioactive decay
- b. Using tape to remove contamination
- c. Scrubbing with soap and water
- d. Physically removing contamination sections by cutting

Same process as lint removal

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LESSON OUTLINE

**INSTRUCTOR
NOTES/KEY AIDS**

G. Work Materials

1. Follow site guidance for control of materials
 - a. Bagging while in contaminated areas
 - b. Proper survey requirements and techniques for removal
2. Decontamination Techniques
 - a. Follow same general rules for clothing
 - b. Control and reuse in contaminated areas to minimize handling and generating wastes
 - c. Expensive or vital materials may undergo chemical, ultrasonic or abrasion decontamination

Consider cost
versus disposal
for inexpensive
items

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

VIII. USE OF PROTECTIVE CLOTHING

A. Introduction

1. Purpose

- a. Provide instruction, demonstration and practice exercise of the proper techniques for donning and removing protective clothing, including proper actions while inside a radiologically controlled area (RCA) and the follow-up actions after removal of the protective clothing

2. Chapter 8 Objectives

TP-8.1

B. Purpose of Protective Clothing

1. Prevent personnel external contamination
2. Reduce possibility of personnel internal contamination
3. Reduce external exposure (beta radiation)
4. Prevent the spread of contamination

Does not
protect/shield
from external
gamma radiation

C. Donning Protective Clothing

1. Full set consists of:
 - a. Coveralls
 - b. Shoe covers (flimsies)
 - c. Rubber shoe covers

Assumption:
licensee will
have specific
requirements for
a full set of PC's

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

- d. Inner Cotton gloves (liners)
 - e. Outer rubber gloves
 - f. "Surgeon" or skull cap
 - g. Cloth hood
 - h. Industrial safety equipment (such as safety glasses, and ear plugs, etc.)
- Provides the least (if any) amount of protection from contamination, generally provided for comfort
-
- 2. Donning of protective clothing may vary from one facility to another such as:
 - a. Types of protective clothing
 - b. Protective clothing requirements
 - c. Levels of contamination
 - 3. Protective Clothing requirements are set by the Health Physics Supervisor or Manager/Department
 - a. Rules/Regulations must be learned prior to entering area(s) requiring the use of protective clothing
 - b. Each licensee has their own requirements for work in a contaminated area
 - c. Cuts/abrasions may prohibit entry into the RCA-Check with HP prior to entry
- "Requirements for work in a Contaminated Area"

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LESSON OUTLINE

**INSTRUCTOR
NOTES/KEY AIDS**

D. Prior to Donning clothing

1. Review RWP requirement
 - a. Protective clothing
 - b. Job description
 - c. Dosimetry requirements
 - d. Expected dose rates, etc.
2. Select clothing large enough to be removed easily, but not cumbersome
3. Check for holes, tears
4. Check for pinhole leaks in rubber/plastic items
5. Remove outer clothing if necessary or required
6. Remove jewelry and other personal items
7. Place dosimetry in proper location and bag if required
8. Prepare tape pieces for seams

TP-8.2

If clothing is torn while in contaminated area, HP should be notified at area exit

Do not blow open with the mouth. Force air into the item.

Modesty clothing should be worn and may be provided by licensee

TP-8.3

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LESSON OUTLINE

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E. Donning Clothing

INSTRUCTOR NOTE: Instructor demonstrates dressout procedure while explaining the following sequence

No specified sequence.
Suggested sequence only

1. Sequence of donning
 - a. Inner (flimsy) shoe covers
 - b. Coveralls
 - c. Rubber overshoes
 - d. Tape ankles TP-8.4
 - e. Safety glasses
 - f. Cap TP-8.5
 - g. Hood
 - h. Dosimetry (normally bagged in thin plastic)
 - i. Tape coveralls TP8.6
 - j. Cotton inner gloves
 - k. Rubber gloves
 - l. Tape wrists TP-8.7
 - m. Conduct final check TP-8.8
2. Outer rubber gloves and taping performed last due to inconvenience
 - Enlist assistance when possible

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

F. Removing Clothing

1. Specified by licensee TP-8.9
2. Normally begin with items most likely to be contaminated
 - a. Overshoes
 - b. Rubber gloves
 - c. Hood
3. Follow licensee procedures at step-off-pad TP-8.10
4. Step-off-pad Note step-off-pads too close together
 - a. Maintain contamination control TP-8.11
 - b. Do not step on them until contaminated/protective clothing has been removed Proper placement at step-off-pad
5. Remove tape and protective clothing slowly
6. Place items in appropriate container at the Step-Off-Pad TP-8.12
7. Health Physics should be contacted prior to removing tools/materials from a contaminated area
8. Remove dosimeters and handle per licensee procedures TP-8.13
9. Do not touch potentially contaminated material with cotton liners

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LESSON OUTLINE

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10. Any mistakes should be reported to HP prior to leaving area
11. Conduct whole body monitoring after removal of all protective clothing
 - a. Equipment used includes personnel monitors, baths or hand-held friskers
 - b. Hand held friskers require approximately 3 minutes
 - Ensure unit is on and working properly
 - Check hands first before touching probe
 - Listen and view response
 - Keep probe ½ inch from body
 - Move probe approximately 2 inches per second
 - Repeat hand check after whole body frisk
 - c. Automated units have instructions posted
12. Response to monitor/frisker alarms
 - a. Look for posted instructions
 - b. Call for HP assistance

Contact should be avoided to prevent contamination of the probe

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LESSON OUTLINE

**INSTRUCTOR
NOTES/KEY AIDS**

13. Complete whole body frisk

a. Obtain dosimetry and materials used (if any)

- Check the reading on the pocket dosimeter
- Complete the RWP sign out and Dose Card

G. Practical Exercise

INSTRUCTOR NOTE: Use Practical Exercise Evaluation form in Appendix A of the Lesson Outline to evaluate trainee knowledge and ability in RWP requirements and use of protective clothing.

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

IX. INDUSTRIAL SAFETY

A. Introduction

1. Purpose

Provide a general overview of industrial safety practices at nuclear power stations

2. Chapter 9 Objectives

TP-9.1

3. Safety is everything we do to prevent accidents and is required for unescorted as well as escorted access

4. Each individual has the responsibility to read, understand, and follow the licensee's safety rules

B. Chemical Hazard

1. A wide variety of chemicals may be encountered at a nuclear power plant

2. The Occupational Safety and Health Administration (OSHA) requires employers to inform employees of the safety and health hazards associated with the use of hazardous chemicals in the workplace (29 CFR 1910.1200)

3. Employers (licensees) are required to maintain Material Safety Data Sheets (MSDS) for all chemical hazards used in their workplace

4. An MSDS lists the safety precautions to be used when working around a specific chemical

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LESSON OUTLINE

**INSTRUCTOR
NOTES/KEY AIDS**

5. Types of Chemical Hazards

- | | |
|--|--------|
| a. Carcinogens | TP-9.2 |
| <ul style="list-style-type: none">• Substances which cause cancer• Examples of carcinogens are benzidine, inorganic arsenic, and formaldehyde | |
| b. Corrosives | TP-9.3 |
| <ul style="list-style-type: none">• Substances which react with sufficient vigor to cause severe injury to living tissue• Examples of corrosives are sodium hydroxide, nitric and sulfuric acid | |
| c. Explosives | TP-9.5 |
| <ul style="list-style-type: none">• Substances which rapidly react to produce gases at sufficient temperature and pressure to cause damage• Examples of explosives are hydrogen and propane | |
| | TP-9.6 |

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

d. Gases TP-9.7

- Substances in a physical state that will diffuse to fill a confining space
- Gases may be hazardous as poisons, flammables, explosives, corrosives or by simply displacing air
- Examples are nitrogen and hydrogen

TP-9.8

e. Poisons TP-9.9

- Substances likely to cause death or serious injury if swallowed, inhaled, or in contact with the skin
- Examples are ammonia and chlorine

TP-9.10

f. Solvents TP-9.11

- Substances used to dissolve material and may present several hazards such as toxicity, corrosiveness or flammability
- Examples are cleaning fluids and degreasers

TP-9.12

C. Live Steam and Hot Liquids TP-9.13

1. Live (hot and under pressure) steam and hot liquids can cause severe injury from burns, cutting, and by causing flying fragments
2. Burns from hot components are one of the most frequent causes of injury at a nuclear plant

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LESSON OUTLINE

**INSTRUCTOR
NOTES/KEY AIDS**

D. Heat Stress

TP-9.14

1. High heat and humidity are principal components which may result in heat stress to personnel

2. Common Heat Illness and Symptoms

TP-9.15

- a. Heat cramps

- Painful spasms of muscles

- b. Heat exhaustion

- Fatigue, nausea, headaches, clammy and moist skin, and fainting

- c. Heat Stroke

May be fatal

- Hot dry skin, high and rising temperature, mental confusion, possibly unconscious

3. Prevention

- a. Acclimatize yourself, if possible

- b. Drink plenty of fluids

Consideration must be given to protective clothing selection when heat stress may be a factor

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LESSON OUTLINE

INSTRUCTOR
NOTES/KEY AIDS

E. Cryogenics

TP-9.16

1. Substances which are maintained at very low temperatures
2. Contact with cryogenics causes severe damage due to spot freezing of the flesh
3. Examples of cryogenics are liquid oxygen, liquid hydrogen and liquid nitrogen

The injury is similar in many ways to burns caused by high temperatures

F. Noise

TP-9.17

1. Noise levels can be very high in some plant areas
2. Levels above 90 dBA may cause hearing reduction or loss
3. Hearing loss is permanent

G. Oxygen Limited Environment

TP-9.18

1. The lowest oxygen concentration in air permitted by OSHA is 19.5%
2. Oxygen deficiencies may be due to displacement, high altitude and oxygen consumption
3. The most common power plant cause is displacement

Such as that when using argon

4. Prior to entering potentially oxygen limited environments, remote measurements should be

TP-9.19

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made

5. Oxygen deficiency may not be sensed and is usually fatal

H. Electrical Shock

TP-9.20

1. Electrical shocks most commonly occur while working on open wires, switches and breakers
2. Treat all open electrical components as energized

Compressed Gases

TP-9.21

1. Hazards arise from cylinder rupture, leaks and mix-ups
2. Safety action includes carefully checking labels and properly securing cylinders

J. Falls

TP-9.22

1. Most commonly treated injuries result from falls and trips
2. Biggest safety tip is to stay constantly aware of your environment

TP-9.23
TP-9.24

K. General Safety Practices

TP-9.25

1. Safety Equipment
 - a. Routinely/required at sites

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LESSON OUTLINE

**INSTRUCTOR
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- b. Types of equipment
 - Hard hats
 - Eye protection TP-9.26
 - Ear protection TP-9.27
 - Sturdy shoes
- 2. Postings
 - a. Identify industrial hazards
 - b. Similar to radiation postings
- 3. Tagging
 - a. Tagging materials and equipment unsafe use is a standard practice at all sites
 - b. A RED tag is normally used to prevent operation or movement of an item
- 4. Permits
 - a. Used to control activities with a high chance at industrial safety problems
 - b. Examples are welding, scaffolding, and continued space entry
- L. NRC and OSHA Memorandum of Understanding
 - 1. Described in USNRC Information Notice 88-100

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

2. Delineates general areas of responsibility between NRC and OSHA to minimize workplace hazards

X. PHYSICAL PROTECTION AND EMERGENCIES

A. Purpose

1. Provide an overview of the physical protection controls and procedures that will be encountered at a nuclear power station and the general procedures for responding to emergencies, drills, and incidents

B. Chapter 10 Objectives

TP-10.1

C. Physical Protection ("Security") of Plants and Materials

TP-10.2

1. Purpose (10 CFR Part 73)

- a. Protect against acts of radiological sabotage
- b. Prevent theft of special nuclear material
- c. Protect safeguards information against
- unauthorized use
- d. Prevent unauthorized access into specific areas

D. Definitions

1. "Authorized Individual" is an individual...who has been designated in writing by the licensee to have...unescorted access...
2. "Isolation Zone" is an area adjacent to a physical barrier which is clear of all objects which could shield an individual

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

3. "Material Access Area" are controlled areas enclosed by barriers and where special nuclear material is present
4. "Physical Barrier" means fences, walls, ceilings and floors constructed of...(specific materials, thicknesses, heights, etc.)
5. "Protected Area" is an area encompassed by physical barriers and to which access is controlled
6. "Safeguards Information" is data, not otherwise classified, which specifically identifies security measures for physical protection and location of certain equipment vital to plant
7. "Vital Area" is any area containing vital equipment
8. "Vital Equipment" is any equipment, system, device or material; the failure, destruction, or release of which could endanger the public by exposure to radiation

E. Performance Capabilities

TP-10.3

1. Licensee must be able to:
 - a. Prevent unauthorized access
 - b. Permit only authorized activities
 - c. Provide for authorized access
 - d. Additional response capabilities associated with the control/movement of special nuclear material

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LESSON OUTLINE

INSTRUCTOR NOTES/KEY AIDS

F. General Levels of Access Control

TP-10.4

1. Owner Controlled property area:

- a. Areas outside barriers are usually not considered part of protection
- b. Access routes and general boundaries are posted

2. Protected Area

TP-10.5

- a. Surrounded by barrier
- b. Vehicles/individuals are identified and searched
- c. No cameras, weapons, explosives, alcohol, drugs
- d. ID badge must be displayed
- e. Unescorted access granted must stay in escort's vision
- f. Can't challenge existing barriers

Normally a fence

TP-10.6

**TP-10.7
TP-10.8**

TP-10.9

TP-10.10

3. Vital Area

- a. Contains vital equipment whose failure, destruction, or loss of service may endanger the public
- b. Normally within the Protected Area
- c. Enclosed by a wall

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LESSON OUTLINE

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- d. Card reader is used for access TP-10.11
- e. Closed circuit video monitored
- f. Similar rules apply to Protected Area
- g. Door should not be pulled on before unlocking
- h. No tailgating

G. Safeguards Information

1. Applies to security plan/procedures, physical protection systems, vital safety equipment and guards
2. Access to information on an "as need to know" basis
3. Must be clearly identified
4. Includes physical protection procedures

H. Emergencies and Drills

1. Alarms, sirens, announcements vary from site to site
 - a. Some standardization:
 - Tones for emergency classifications
 - Tones for fire, medical or first aid response

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LESSON OUTLINE

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- Bells/Buzzer for local alarm
- Solid tone for a message or test

2. Response

- a. Obey assembly, evacuation or "stand-fast" orders
- b. Radiological Emergency
 - Exit area and report to designated area
 - 4 levels of emergencies
 - NOUE and Alert require no evacuation
 - SAE and General Emergency usually require evacuation
- c. Fire/Medical Alarm
 - Listen for announcement/standby for further instructions
 - Take appropriate action if emergency can be seen
- d. Local Area Alarm
 - Exit area immediately
 - Report to HP or Safety Department
- e. Unless specific duties are assigned remain out of the way

NOUE, Alert,
SAE and
General
Emergency

Example:
Continuous Air
Monitor (CAM)
Alarm

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LESSON OUTLINE

**INSTRUCTOR
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3. Injuries

- a. Primary concern-medical treatment
- b. Take necessary steps to avoid complications
- c. Know how to request assistance
- d. Obtain HP approval prior to entering a RCA with an open wound or broken skin

4. Incidents

a. Radioactive Spill Procedure (SWIMS)

TP-10.12

- Stop the spill
- Warn others
- Isolate the area
- Minimize your exposure
- Secure non-filtered ventilation

b. Area Radiation/Airborne Alarms

TP-10.13

- Leave area
- Notify HP/Safety

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**INSTRUCTOR
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- c. Off-Scale, Lost, Damaged Dosimetry
 - Inform others in area
 - Promptly report to HP
 - Greater than $\frac{3}{4}$ of scale may be treated as "off scale".
- 6. Personnel/Clothing contaminations
 - a. Standby and request HP assistance
- 7. Respiratory Protection Problem
 - a. Immediately leave area
 - b. Remove mask if it becomes difficult to breathe while wearing a respirator
- 8. General Problem/Alarm
 - a. Act with minimal impact to emergency operations

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LESSON OUTLINE

**INSTRUCTOR
NOTES/KEY AIDS**

XI. REVIEW

- A. Clarify remaining trainee questions or concerns
- B. Review examination procedure and passing criteria
- C. Administer examination